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ScienceDirect
Fisheries Research 81 (2006) 86–88
FISHERIES RESEARCH
www.elsevier.com/locate/fishres

Short communication

Seasonal sea turtle mortality risk from forced submergence in bottom trawls

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Received 23 January 2006; received in revised form 25 April 2006; accepted 25 May 2006

Abstract

The risk of mortality to sea turtles with increasing trawl tow time was assessed in two seasons, summer and winter. Tows of 10 min or less had negligible mortality in both seasons while intermediate tow times resulted in rapid escalations in mortality before reaching a plateau of high mortality. Mortality increased more quickly in winter than in summer.

Keywords: Sea turtles; Mortality; Trawl; Logistic regression

1. Introduction

Prior to the introduction of turtle excluder devices (TED) in the shrimp trawl fishery of the southeast United States, this fishery was estimated to have caused more sea turtle mortalities from this area than all other human activities combined (National Research Council, 1990). While that impact has been greatly reduced by the use of TEDs in the U.S. shrimp fishery, other trawl fisheries within and outside the U.S. operate without TEDs and are known to cause sea turtle mortalities (see Casale et al., 2004; Epperly et al., 1995). In addition, under special environmental conditions, tow time limits of 55 min from April 1 to October 31 and 75 min from November 1 to March 31 are occasionally permitted for use by the shrimp fishery in lieu of TEDs (Federal Register, 2005). For try nets and skimmer trawls in the shrimp fishery, these tow time limits are required in place of TEDs (Federal Register, 1992; Federal Register, 2003).

Henwood and Stuntz (1987) noted that mortality rate is a function of tow time. Turtles captured in trawls are likely to be forcibly submerged for lengths of time greater than their average dive times which may result in the turtle becoming comatose and eventually drowning (Lutcavage and Lutz, 1997). Tolerance for forced submergence is affected by turtle size, turtle activity, and water temperature (Lutcavage and Lutz, 1991; Stabenau et al., 1991). A 1989 summary report of a National Marine Fisheries Service sea turtle mortality workshop noted that to an observer or fisherman in the shrimp fishery a comatose turtle would appear to be dead as the turtle may show no signs of breathing for 1 h and have a heart rate of only 3 beats/min. A failure to resuscitate comatose turtles is likely to result in their death as they are unable to swim and likely unable to breath. Due to the likelihood that any comatose turtles returned to the water die, the National Research Council (1990) recommended that any estimates of mortality include both dead and comatose turtles.

The continued impact of forced submergence in trawl fisheries, along with many other gear types, on sea turtles worldwide and the recommendation of counting dead and comatose turtles as mortalities suggested that a re-analysis of the Henwood and Stuntz (1987) data may provide some additional insight into turtle mortality and tow time/forced submergence.

2. Methods

We analyzed a data set, used by Henwood and Stuntz (1987), from three National Marine Fisheries Service fishery observer programs during 1973–1984. Henwood and Stuntz (1987) assessed mortality versus time fished broken into

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0165-7836/$ – see front matter
doi:10.1016/j.fishres.2006.05.016

intervals of 30 min. The National Research Council (1990) revisited the data and found substantial differences in mortality between seasons using time intervals of 10 min. They pointed out that Henwood and Stuntz (1987) assumed all comatose turtles survived and also noted that all resuscitated individuals do not survive. Following the recommendation of the National Research Council to divide the data by season and assume comatose turtles were mortalities, we re-analyzed the dataset to estimate the proportion of dead turtles captured with increasing tow times (fishing time) by bottom trawls. It should be noted that we considered including additional data from a study of sea turtle and shrimp fishery interaction ($n = 317$) conducted by the Gulf & South Atlantic Fisheries Foundation in 1997 and 1998. However, we found that inclusion of these data yielded essentially identical results to the Henwood and Stuntz (1987) dataset by itself and elected to proceed with just the Henwood and Stuntz dataset to be consistent with their publication and National Resource Council (1990) analysis.

The data were divided into two seasons based on the effort level of the shrimp fishery as well as expected water temperatures: a warm water period (summer), March–November, when the fishery is most active, and a cold water season (winter), December–February, when fishery effort is lower with most of the activity occurring offshore in the Gulf of Mexico.

Consistent with the Henwood and Stuntz (1987) analysis, all sea turtles species are included in our analysis dataset for a total of 4358 turtle captures, nearly all loggerheads (*Caretta caretta*). The original dataset was edited in the late 1990s (Henwood, personal communication), possibly explaining the difference in sample size with Henwood and Stuntz (1987: $n = 4624$) and the National Research Council (1990: $n = 4397$).[1] Turtles captured by location and season were as follows: 2886 were alive and 371 were dead in the Atlantic during the summer period; 959 were alive and 93 dead in the Atlantic during the winter; 10 were alive and 33 were dead in the Gulf of Mexico during the summer period; 3 were alive and 3 were dead in the Gulf of Mexico during the winter.

Logistic regression (Sokal and Rohlf, 1995) was then used with the turtle trawl capture data to model tow time versus the proportion of turtle mortality in tows for both seasons using the statistical program SAS (Version 8, SAS Institute, Cary, NC). In addition, a combined model with tow time and season was run to determine if mortality was different between the seasons. Overall significance of a model was determined using the deviance of the model and the predictive ability of the model was assessed using the calculated r-square and Somers' D_{xy} statistics. For the combined model, the odds ratio was used to determine if mortality was higher in winter or summer.

[1] In their publication Henwood and Stuntz (1987) do not report the sample size for their mortality estimates, but their earlier unpublished report contains the detailed information (Henwood and Stuntz, 1986). Their original dataset primarily was trawl data, but there were data from non-trawl sources. It is likely that these data were not provided to the National Research Council or they did not use them for their analyses, and were edited from the database prior to our analysis.

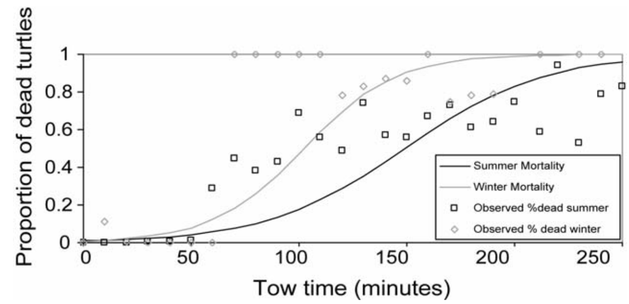

Fig. 1. Logistic curves and observed proportion of sea turtle mortalities relative to tow time in summer and winter.

3. Results

The models for both summer ($\text{logit}(p) = -4.6815 + 0.314 \times \text{tow time}$; deviance = 346.61, d.f. = 151, $p < 0.0001$) and winter ($\text{logit}(p) = -4.7967 + 0.469 \times \text{tow time}$; deviance = 121.26, d.f. = 59, $p < 0.0001$) were significant, and accounted for 62 and 70% of the variation in summer and winter, respectively, based on the calculated r-square values. The models are a good representation of the pattern in the data as there was a high association of the predicted probabilities with the observed responses in summer (Somers' $D_{xy} = 0.914$) and winter (Somers' $D_{xy} = 0.899$). The combined model indicated that mortality was different between the seasons ($p < 0.0001$) with mortality being higher in the winter than in summer (Odds ratio = 2.61:95% CI 1.83–3.73).

For both seasons, tows of short duration (<10 min) have negligible likelihood of turtle mortality (defined as <1% by Henwood and Stuntz, 1987; National Research Council, 1990), intermediate tow times result in a rapid escalation in mortality (10–200 min in summer and 10–150 min in winter), and eventually reach a plateau of high mortality (Fig. 1). Mortality will be high on long tows, but will not always equal to 100% as a turtle caught shortly before the end of a long tow would likely survive.

4. Discussion

The findings here expand upon what has been reported by the National Research Council (1990) and Henwood and Stuntz (1987). Specifically, tows of short duration (<10 min) have negligible effect on mortality. Additionally, the recommendation of the National Research Council to examine the data by season was warranted as demonstrated by these results. One unique finding here is that the mortality rate of turtles is predicted to rise faster in winter than it is in summer (Fig. 1). This prediction suggests that it may not be conservative to allow the longer fishing times of 60 min in the winter and 40 min in summer as recommended by the National Research Council (1990).

Forcibly submerging a turtle for extended periods in fishing gear is of concern as the physiological responses to forced submergence are markedly different from that of a normal dive (Lutcavage and Lutz, 1997; Stabenau et al., 1991). Notably, within 30 min of forced submergence the heart rates of non-swimming turtles sharply decline, blood lactate levels increase, and blood oxygen is depleted to very low levels. When compared to restrained turtles, the lactic acidosis of free-swimming turtles placed in the mouth of a trawl is more rapid. Stabenau et al. (1991) found that swimming turtles experienced significant changes in blood parameters during brief forced submergences (3–7 min). In addition, recovery to pre-submergence lactate levels takes several hours (Stabenau and Vietti, 2003), sometimes as long as 20 h (Lutz and Dunbar-Cooper, 1987). The long recovery time is of particular concern as turtles that experience multiple captures are likely to be even more susceptible to lethal acidosis (Lutcavage and Lutz, 1997). However, with the introduction of TEDs, multiple submergences of a turtle should not affect an individual's survival if there is an adequate rest interval at the surface where the animal can recover from the acidosis by hyperventilating (Stabenau et al., 1991; Stabenau and Vietti, 2003).

Furthermore, while the general physiological effects of forced submergence are generally understood, the effects of water temperature on mortality risk also need to be considered given our finding that longer tow times in the winter season may not present a reduced risk to turtles. While the demand for oxygen may be higher at warmer temperatures (Lutcavage and Lutz, 1997), perhaps the stress of lower water temperatures on poikilotherms may result in reduced tolerance of forced submergence. Lutz and Dunbar-Cooper (1984) noted that captive turtles showed signs of stress in cold water temperatures. Specifically, they noted that when the temperature rapidly changed at a rate of 2.5 °C/day, from 30 to 10 °C under controlled conditions, there is a failure of important metabolic processes between 10 and 15 °C with behavior disturbances occurring in some individuals at temperatures under 20 °C and most by 15 °C. Moon (1992) reported that captive turtles exposed to a slowly declining temperature of 5–6 °C/week under controlled conditions also showed signs of stress. Those turtles stopped feeding when water temperature dropped below 15 °C and were semi-dormant, but on the bottom, from 9 to 15 °C. Given the physiological and behavioral effects of cool water temperatures the finding that the risk of mortality increases more quickly in the winter is not surprising.

Although the data presented here are specific to the observed bottom trawl gear in the U.S. shrimp fishery, the findings are applicable to the impacts of forced submergence in general. Our models indicate that tow time would need to be to 10 min or less for both seasons in order to achieve the negligible mortality of <1% as defined by Henwood and Stuntz (1987) and the National Research Council (1990). The observed mortality exceeded 1% after 10 min in the winter ($n = 3$). The observed mortality in summer did not exceed 1% until after 50 min ($n = 13$), with turtles reported dead in tows as short as 15 min ($n = 2$). These observations are consistent with the physiological effects of forced submergence reported by Lutcavage and Lutz (1997) and Stabenau et al. (1991) where brief submergences resulted in dramatic heart rate declines, increased blood lactate levels, and blood oxygen depleted to dangerously low levels.

Acknowledgments

We wish to thank all of those involved in the original collection of this data, and especially T. Henwood for supplying the original data set for this analysis. We thank Jim Bohnsack, Terry Henwood, and the anonymous reviewers for providing helpful comments.

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